Calculation of \( (n,\alpha) \) reaction cross sections by using some Skyrme force parameters for Potassium (\(^{41}\text{K} \)) target nuclei

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Abstract. In this study, the \((n,\alpha)\) nuclear reaction cross section was calculated for \(^{41}\text{K} \) target nuclei for neutron and proton density parameters using SKa, SKb, SLy5, and SLy6 Skyrme force. Theoretical cross section for the \((n,\alpha)\) nuclear reaction was obtained using a formula constituted by Tel et al. (2008). Results are compared with experimental data from EXFOR. The calculated results from formula was found in a close agreement with experimental data.

1 Introduction

Potassium (with a symbol K, \(Z=19\)) presents in some fruits and vegetables such as peach and melons etc. [1-3]. In recent years, Potassium has been used in different area like medicine and agriculture etc. [1-5]. Nowadays, nuclear reactions have been using different cross section formula similar to Tel et al. formula [6]. The Hartree-Fock-Skyrme-Method is used for studying the properties and structure of nuclei [7-12]. In addition, many properties of nuclei are calculated using this method such as proton (\(\rho_p\)) and neutron (\(\rho_n\)) densities. In this calculation, we investigated the proton (\(\rho_p\)) and neutron (\(\rho_n\)) densities for \(^{41}\text{K} \) target nuclei using the Skyrme-Hartree-Fock [8, 10, 11] calculation method with the SKa, SKb, SLy5, and SLy6 force parameters [7, 13, 14]. From these calculations, the new proton and neutron densities were obtained. The theoretical results calculated for proton (\(\rho_p\)) and neutron (\(\rho_n\)) densities were used in the formula given by reference [6] for the \((n,\alpha)\) nuclear reaction cross section at incident neutron energy of 14-15 MeV [6].

2 Results and Discussion

In this study, we calculated the \((n,\alpha)\) theoretical nuclear reaction cross section for \(^{41}\text{K} \) target nuclei. We used SKa, SKb, SLy5, and SLy6, Skyrme force parameters for calculations [7, 13, 14]. SKa, SKb, SLy5, and SLy6, Skyrme force parameters were given in Table 1 and Fig. 1-4. These parameters were then used in the Skyrme-Hartree-Fock Program (HAFOMN) [11, 15]. Cross section calculations were obtained for target nucleus with radius of 1.8 fm and then were compared with the semi-empirical results constituted by Tel et al. formula [6]. For the mass numbers between 37 and 239, this formula is given as follows [6];

\[
\sigma_{(n,\alpha)} = 16.15(A^{1/3} + 1)^2 e^{-3.04s} \tag{1}
\]

where \(A\) is mass number of atom, \(s\) is asymmetry parameter (\(S=(N-Z)/A\)).

Table 1. SKa, SKb, SLy5, and SLy6 Skyrme Force Parameters [7, 13, 14].

<table>
<thead>
<tr>
<th></th>
<th>SKa</th>
<th>SKb</th>
<th>SLy5</th>
<th>SLy6</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_0 )</td>
<td>-1602.78</td>
<td>-1602.78</td>
<td>-2484.88</td>
<td>-2479.50</td>
</tr>
<tr>
<td>( t_1 )</td>
<td>570.88</td>
<td>570.88</td>
<td>483.13</td>
<td>462.18</td>
</tr>
<tr>
<td>( t_2 )</td>
<td>-67.70</td>
<td>-67.70</td>
<td>-549.40</td>
<td>-448.61</td>
</tr>
<tr>
<td>( t_3 )</td>
<td>8000</td>
<td>8000</td>
<td>13763</td>
<td>13673</td>
</tr>
<tr>
<td>( t_4 )</td>
<td>125</td>
<td>125</td>
<td>126</td>
<td>122.00</td>
</tr>
<tr>
<td>( x_0 )</td>
<td>-0.02</td>
<td>-0.02</td>
<td>0.778</td>
<td>0.825</td>
</tr>
<tr>
<td>( x_1 )</td>
<td>0</td>
<td>-0.165</td>
<td>-0.328</td>
<td>-0.465</td>
</tr>
<tr>
<td>( x_2 )</td>
<td>0</td>
<td>0</td>
<td>-1.00</td>
<td>-1</td>
</tr>
<tr>
<td>( x_3 )</td>
<td>-0.286</td>
<td>-0.286</td>
<td>1.267</td>
<td>1.355</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>1/3</td>
<td>1/3</td>
<td>1/6</td>
<td>1/6</td>
</tr>
</tbody>
</table>

In earlier works, neutron and proton data for asymmetry parameter (\(S=(N-Z)/A\)) were used. But, for this study, we used in the formula developed by Tel et al. [6] proton and neutron density data for asymmetry parameter (\(S=(\rho_p-\rho_n)/\rho_n\)) [6,7,9]. Theoretical cross section values obtained with the cross section values \(^{41}\text{K}(n,\alpha)\)\(^{23}\text{Cl} \) results that are obtained using SKa, SKb, SLy5, and SLy6 parameters are given in Table 2 [7,13-14]. The neutron-number (\(N=22\)) and neutron densities (\(\rho_n\)) are higher than proton-number (\(Z=19\)) and proton densities (\(\rho_p\)) because of \(Z=19\) and \(N=22\) for \(^{41}\text{K} \). The obtained value of the proton density (\(\rho_p\)) for \(^{41}\text{K} \) target nuclei at the \(r=1.8\) fm have approximately been from 0.075 (for SKa and SLy5), 0.074 (for SKb), 0.079 (for SLy6) [7, 13, 14]. Moreover, value of the neutron density (\(\rho_n\)) for \(^{41}\text{K} \) target nuclei at the \(r=1.8\) fm have
approximately been from 0.081 (for SKa and SKb), 0.082 (for Sly5), 0.087 (for SLy6) and also obtained value of the asymmetry parameter for $^{41}$K target nuclei at the 0.040 (for Ska), 0.043 (for SKb and SLy5), 0.044 (for Sly6) [7, 13, 14]. (see Figs. 1-4 and Table 2). Many experimental data were found from 1953 to 2017 for Potassium (for $^{41}$K(n,α)$^{38}$Cl) [16]. Some experimental cross sections data were given in this study. For example; Garuska et al. found the cross section to be 30 ± 3 mb at 14.6 MeV neutron induced reactions [16, 17]. Filatenkov et al. found the cross section as to be 34.7 mb ± 1.6 mb at 14.1 ± 0.1 MeV neutron induced reactions [16-18]. Ercan et al. determined the experimental cross section as to be 36 ± 3 mb at 14.6 ± 0.1 MeV neutron induced reactions [16, 19]. Ikeda et al. found the cross section to be 37.6 ± 2.8 mb at 13.97 MeV neutron induced reactions [16, 20]. Anders et al. found the cross section as to be 33 ± 1.3 mb at 14.7 ± 0.3 MeV neutron induced reactions [16, 21]. Bormann et al. found the cross section to be 12 ± 5 mb at 14.1 ± 0.05 MeV neutron induced reactions [16, 22]. Janczyszyn et al. found the cross section as to be 11 ± 2 mb at 14.0 MeV neutron induced reactions [16, 23].

Table 2 Theoretical cross section results for $^{41}$K(n,α) nuclear reactions for r=1.8 fm

<table>
<thead>
<tr>
<th>SHF</th>
<th>Proton densities</th>
<th>Neutron densities</th>
<th>Asymmetry parameter</th>
<th>σ_Theo (mb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ska</td>
<td>0.075</td>
<td>0.081</td>
<td>0.040</td>
<td>10.08</td>
</tr>
<tr>
<td>SKb</td>
<td>0.074</td>
<td>0.081</td>
<td>0.043</td>
<td>9.086</td>
</tr>
<tr>
<td>SLy5</td>
<td>0.075</td>
<td>0.082</td>
<td>0.043</td>
<td>9.142</td>
</tr>
<tr>
<td>SLy6</td>
<td>0.079</td>
<td>0.087</td>
<td>0.044</td>
<td>9.046</td>
</tr>
</tbody>
</table>

We compared our data of target $^{41}$K with literature data from EXFOR around 14-15 MeV [16, 18]. In this study, the obtained neutron and proton density results were depicted in Figs. 1-4. For neutron incident energy at 14.00 MeV, the experimental data is 11 ± 2 mb [23] and theoretically calculations are about 10.08 mb for Ska, 9.086 mb for SKb, 9.142 mb for SLy5, and 9.046 mb for SLy6 at r = 1.8 fm. These parameters were then used in the Skyrme-Hartree-Fock-program (HAFOMN) [7, 13-15]. Empirical results are found in compatible with theoretical data obtained in reference [6].

**3 Conclusion**

Many researchers have studied experimental and theoretical cross sections in recent years. In this study, (n,α) nuclear theoretical cross section reactions have been investigated for $^{41}$K target nuclei incident neutron energy of 14-15 MeV. The attained data have also been contrasted on the existing some experimental values in EXFOR [16]. The attained theoretical and experimental results can be explained as follows;

In order to be calculate (n,α) reaction cross section, we used the formula developed by Tel et al. formula [6]. In Equation 1 developed by Tel et al. [6] can be used to calculate cross section with SKa, SKb, SLy5 and SLy6 Skyrme-force-parameters for $^{41}$K target nuclei [7, 13-14]. The obtained results were compared with experimental result for 1.8 fm radius (see Figs. 1-4). In order to be calculate (n,α) different radius reaction cross section for $^{41}$K target nuclei, we used Tel et al formula [6] and we obtained theoretical cross section agreement with experimental results (see Figs. 1-4).
Fig. 4. $^{41}$K(n,α)$^{38}$Cl SKa proton and neutron density values

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References